THE PROBLEMS OF SAFETY IN A NUCLEAR POWER INDUSTRY

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ABSTRACT

This paper attempts to analyse the safety problems during the operation of nuclear power plant, the responsibility of the government to the safety of the public, environmental hazards from radiation effluents, safety in transportation of nuclear materials, nuclear waste product management and safety regulations in an isotope laboratory.

PREAMBLE

The number of countries joining the "nuclear club" despite out-cry and demonstrations on the establishment of Nuclear Power Plants is in the increase. The innate fear of nuclear radiation emanating from the memory of awe some effects of the atomic bomb explosion over Hiroshima and Nagaski, the long-span rate of radioactive disintegration example.

Thorium — 232, which has 1.39X10 16 years
Uranium — 238, 4.51×10^9 years
Plutonqum — 239, 2.41×10^4 years ; the problem of spent-fuel management the development of the Fast Breeding Reactor (FBR) with its potential conversion of plutonium by over-zealous nationalists for military applications and the recent development of neutron bombs that could destroy cells of living organisms and leave untouched material substances tend to give vent to this public out-cry.

The question is which of engineering structures and devices:— convectional power stations, electrical machinery, motor cars, bridges houses, and offices etc. that do not present some elements of risks to their owners or operators and to the general public? A peace-loving citizen who appreciates his comfortable home and his private car will understand the necessity of securing the supply of energy. For him, as a member of a society that is used to consumption, the historic experiences of nuclear destruction, is buried, and only a subconscious mistrust of the production of energy by means of nuclear fission is left. This is caused by his being conscious of the awareness of the government and industry of the very important role which safety must play in the design and operation of every nuclear installation.

INVOLVEMENT AND RESPONSIBILITY OF THE GOVERNMENT:

The ultimate responsibility for the protection of the public lies with the government, state, national or both. The manner in which this responsibility is carried out in case of nuclear energy varies from country to country, But the basic principle being the formation of a governmental organization for the regulation of nuclear power plant. In many countries this organization is known as "the Atomic Energy Commission". The responsibility of the Atomic Energy Commission for the regulation of nuclear energy extends over the whole fuel cycle, from the mining and processing of uranium ore through the utilization of the fuel in reactors, the transportation and reprocessing of the spent fuel and the disposal of radioactive wastes. This commission is also responsible for the licensing and inspection of reactor plants in order to provide assurance of safety to the public. Licensing of a reactor facility involves two main stages —

(a) granting of a construction permit and
(b) issuance of an operating license.

The application for a construction permit is accompanied by a Preliminary Hazards Report, the purpose of which is to provide sufficient information for an evaluation to be made of the potential hazards that might arise both from normal operation of the ractor plant and from the consequences of credible accidents. The most important part of the report will consist of a discussion of all conceivable potential hazards together with the steps taken in the design of the system to minimize their consequences.

SITING

The location of a nuclear reactor has an obvious bearing on the consequences to the public of a reactor accident . In choosing a site for the reactor the following factors are carefully considered.

(a) POPULATION DISTRIBUTION:
For the purpose of evaluating a proposed reactor site the ICRP — the International Committee on Radiation Protection has defined two areas in the vicinity of the reactor.

(i) An exclusion area or exclusion zone which is "that area surrounding the reactor in which the reactor license has the authority to determine all activities including exclusion or removal of personnel and property from the area... Residence within the exclusion area shall normally be prohibited. In any event, residence shall be subject to ready removal in case of necessity.

(ii) A low population zone is "the area immediately surrounding the exclusion area, which contains residents, the total number and density of which are such that there is a reasonable probability that appropriate protective measures could be taken on their behalf in the event of a serious accident. The boundaries of these two areas are defined in terms of "maximum credible accident" — accidents caused by the radioactive gases released by either meltdown or disruption of the reactor core, or the rupture of the coolant line. In practical terms the "exclusion area is of

such a size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem". On the other hand, the "low population zone is of such size that an individual located at any point on its outer boundary who is exposed to the radioactive cloud resulting from the postulated fission product release (during the entire period of its passage) would not receive a total radiation dose to the whole body in excess of 25 rem". Another aid in site evaluation, is the population centre distance defined as "the distance from the reactor to the nearest boundary of a densely populated centre containing more than 25,000 residents". In the United States of America, the exclusion area is of radius 33 metres from the reactor, low population centre distance is 200 meters.

(b) *Physical characteristics of site.*

The soil structure, the hydrology of the site and the meteorology of the area must be taken into consideration before final decision is taken on the reactor location.

(i) *Geology of the site*

Detailed analysis of the proposed site must be made to ascertain whether it could support the reactor building with all its internal components.

(ii) *Hydrology of the site.*

This must be examined to ascertain if there is any danger that leakage discharge of contaminated liquids from the plant, during normal operation or in the event of an accident will enter nearby supplies of drinking water or bathing facilities.

(iii) *Meteorology of the area*

This must be reviewed with special reference to the possible effects of prevailing winds and the rainfall pattern in carrying airborne radioactivity from the reactor site to populated areas. A very glaring example of the effect of the prevailing winds is the biological effects of the harmattan winds blowing from a Thorium content region — the Sahara Desert on the vegetation and people of this country.

REACTOR DESIGN AND OPERATION:

The reactor design will include inherent safety features as mechanical safeguards of various kinds to deal with specific situations. Among the inherent safety factors are a negative temperature coefficient reactivity and a negative void coefficient. In the former case an undesirable increase of temperature will be automatically compensated by a decrease in reactivity which will drop the reactor power and, hence, the temperature. A negative void coefficient means that there will be a decrease in reactivity should the fuel temperature rise to such an extent as to cause vaporization or excessive boiling of the coolant.

In each aspect of the design of the reactor system, reliability and safety are given prime considerations. The control-rod- drive mechanism is such that an absorber rod is inserted rapidly but removed only at slow rate. To prevent burnout of the fuel elements, the maximum permissible heat flux is determined, with an adequate factor of safety. The characteristic of the coolant circuit are designed to make sure this flux is not exceeded in normal operation. Some consideration is given to the use of "nuclear safety fuses" which cause a neutron poison to be injected into the core, and thus the reactor down, if the temperature exceeds a certain predetermined value.

It is the practice that only materials whose properties are well known to be stable under the operating conditions of the plant, including radiation exposure, are used for fuel, coolant, and safety-related structures. The reactor is provided with an emergency core cooling system to prevent the meltdown of the fuel and release of fission products due to fission product heating following a loss-of-coolant accident.

To prevent the escape of radioactivity, nuclear plants are designed using the concept of multiple barriers. The barriers represent a sequence of obstacles to block the passage of radioacative atoms from the fuel, or wherever they may originate, to the surrounding population. The following barriers are employed to ensure safe operation the fissible and fissionable material is located within solid fuel elements — as natural or enriche[illegible]nium, in an oxide or carbide form, or in di[illegible]lloy of some structural material —

Zirconium, Aluminium or stainless steel. In PWR (Pressured Water Reactor) and BWR (Boilding Water Reactor) fuel rods, the gases which escape from the surface of the UO 2 (Uranium Dioxide) pellets are held in the pellet-cladding gap and collect in a small plenum provided at the end of each fuel rod. To prevent the escape of the fission product and to confine the fission fragments emitted near the surface of the fuel, the fuel is surrounded by a layer of cladding. Materials used for cladding include Zircaloy, stainless steel and pyrolytic carbon. In all modern power reactors, the primary coolant moves in one or more closed loops. Fission products that have escaped from the fuel, activated atoms picked up by the coolant, and activated atoms of the coolant itself are thus confined within the coolant system. Moreover, in most reactors, a portion of coolant is diverted on a continuing basis into a coolant purification system, where most of the fission products and other radioactive atoms are removed. Reactor vessel represents an obvious barrier to the release of radioactivity. Reactor vessels are therefore designed, manufactured and tested to meet the highest standards of quality and realibility. A very important safety feature in a nuclear plant is the presence of what is known as the biological shield. This is placed around a nuclear reactor and at various points in a nuclear power plant, in order to protect operating personnel and the public at large from the radiations emanating from the installation.

In the reactor house itself, entrance is via a reception area where an automatic meter checking the amount of dose accumulated is installed. Here also a pocket dosimeter is issued. The reception area leads into the changing rooms where a complete change of clothing will be required. It is the general practice that everyone working in the reactor house is given a free litre of milk daily by his employers.

ENVIRONMENTAL PROTECTION

The management of radioactive waste involves two fundamental approaches: the radioactive materials can be either released or changed to the environment, or they must be confined and isolated from the biosphere until the noxious radionuclides have decayed to innocuous concentrations. Releases of radioactivity to the environment generally occur as liquid or gaseous discharges (effluents) from nuclear facilities. The amount of radioactivity which can be released is based on allowable exposures to population groups and is controlled by national regulations and guidelines, usually based on recommendations of the ICRP. Radioactive Wastes could be grouped as: Mill tailings, effluents from Uranium refinning and enrichment, wastes which could be closely classified as high-level, intermediate or low-level and solid wastes.

Uranium mill tailings do not present a serious hazard in open well-ventilated areas. The principal concern involves the possibility of hazardous concentrations of radon gas from the decay of the relatively small amounts of radium 226 in the tailings. Tailings disposal areas can be appropriately located, managed and isolated. The technology exists to stabilize these tailings with a ground cover and vegetation and to protect them in other ways, in order to prevent their dispersion by wind. water and man. It is the normal practice that tailing areas are recorded with the state land perpetuity being placed on their use.

The gaseous effluents from reactor operations may contain radioisotopes of the gases principally argon-41. krypton-85 and Xenon-133, the radioiodines-129 and - 131. tritium and oxides of carbon-14. The radioiodines are eliminated from gaseious waste streams by counter-current srubbing of the gas with aqueous solutions of caustic, mercuric nitrate, nitric acid, or by chemical adsorption on zeolites treated with silver. Cryogenic (low temperature) seperation methods are used for removal of krypton-85 and Xenon-133

Carbon-14 is removed in the oxide form from gaseous effluents by caustic scrubbing or adsorption on solid alkaline media. Basic treatment techniques available to reduce levels of radioactivity in liquid waste streams are filtration and centrifugation, evaporation, ion exchange, flocculation, and precipitation. See page ponds are also used for liquid wastes containing very low concentration of the shorter-lived fission products. Incineration and steam distillation techniques are available for the treatment of radioactive organic oils and solvents. Land burial and sea dumping are utilized for the disposal of intermediate and low level solid waste.

USSR has demonstrated the safe injection of intermediate and low-level liquid wastes into porous formations in deep geologic structure. In the U.S.A., Oak Ridge National Labouratory is demonstrating the injection of a mixture of liquid waste and solidifying agents into shale seams by hydrofracture. The disposal of solid wastes in an underground salt formation is being demonstrated in the Federal Republic of Germany.

RADIATION PROTECTION SERVICES

All persons working within areas where nuclear radiations may be encountered must wear individual personnel monitoring devices; two types of such instruments are in general use.

(a) pocket (ionization chamber) meters and (b) film badges (film dosimeters) In addition to these meters which give the total accumalted radiation dose over a period of time, an aspect of personnel monitoring is a radiation survery of individuals leaving an area where contaminat—ion is possible. One method employed in to use a G-M (Geiger-Muller) survey meter and to run the probe containing the tube over all parts of the body to detect the possible presence of radioac—tivity. If the individual or his clothing is found to be contaminated, appropriate decontamination measures must be taken.

SAFETY IN TRANSPORT OF RADIOACTIVE MATERIALS

The principle adopted for achieving an acceptable standard in the transportation of Radioactive-Materials is that package should provide adequate containment together with sufficient shielding to retain the level of external radiation within prescribed limits. Simple stowage and segregation rules, based on the level of radiation in surroundings of each package as indicated on the attached label, are then applied to ensure that, even for consignments of large number of packages, the levels of radiation will not exceed acceptable values for individuals. The package must be fitted with a positive fastening device which cannot be opened acciden-tally by any action from outside or by pressure variation arising within the package. If the package is heavy, a tie-down system is provided which prevents it from moving and possibly damaging its surroundings during transportation. Other safety requirements during transportation include viz:

(a) provision for rapid notification and dis-patch of trained and equipped teams to recover any consignment under threat.

(b) use of escorts or guards in the same vehi-cle as the consignment and possibly in accompanying vehicles.

(c) provision of rapid communication sys-tem between consignor and consignee to indicate the precise time of departure or arrival.

(d) planning of the transportation to ensure the minimum travel time and minimum number of transfers.

(e) continuous communication with the transport vehicles, and reports from check-points.

(f) the preferential use of air-craft, inclu-ding helicopters.

RADIATION STANDARDS IN TERMS OF THE MAXIMUM PERMISSIBLE DOSE.

Instruments and various body organs with regard to their reaction to radiation are classified under the following groups:-

(i) group 1 — red-bone marrow, gonads
(ii) group 2 — lenses of the eye
(iii) group 3 — bones, skins
(iv) group 4 — hands, forearms.

The maximum permissible dose is normally based on group I. Maximum permissible doses are recommended for two classes of irradiated groups.

Group A — radiation workers
Group B — people irradiated as a result of work in a neighbouring radiation source.
Total dose accumulated for radiation workers is calculated from the relationship.

D — 5(N-18)
Where D is the total dose accumulated in rems.
N is the age of the worker.

Maximum permissible dose for radiation workers for groups 2,3,4

Groups	Quarterly dose (rem)	Yearly dose (rem)
2	4	15
3	8	30
4	20	75

Weekly dosage of a worker in group A should not be more than 0.1 rem, while an individual in group B the dosage should not be more than 0.03 rem. Usual working period of radiographers is 4hrs 4 days per week

REGULATIONS FOR AN ISOTOPE LABORA-TORY

These are the set of regulations deviced for the isotope laboratory of the Energy Resources Unit of Mechanical Engineering Department, University of Nigeria, Nsukka. It is also recommended that these regulations be observed in any isotope laboratory in the country.

Before commencement of work with radio-active materials by the student, it is necessary for him to inform the safety officer his earlier association with such materials and where possible the amount of dosage he has accumulated.

It is unnecessary to carry into the laboratory top coats, caps, wrist-watches, marriage rings and any other personal belongings.

Drinking, eating, smoking and the applica-tion of cosmetics are prohibited.

Without the pre-agreement of the head of the laboratory, any radiation source should not be brought into the laboratory.

Pipetting of any liquid in the laboratory is completely prohibited.

Special sandals and aprons for the laboratory must always be used.

The pocket dosimeter must always be checked before and after work in the laboratory.

No student with cuts (wound) would be allowed into the laboratory.

A high degree of cleanliness and orderliness must be maintained throughout working period.

It is necessary while working with a radioisotope to check the pocket dosimeter at every stage of the experiment.

It is prohibited to handle any isotope. Handling is carried out by specially designed biceps.

All radioisotope containers must have the convectional sign on it with the strength of the particular isotope labelled.

Any suspicion of irradiation should immediately be reported to the safety officer incharge of the laboratory.

At the end of the days work in the laboratory it is absolutely necessary to wash the hands

Students are expected to report for medical check-up at the end of each term

CONCLUSION

From the analysis of the paper, it is evident that so far, there is no engineering complex where so much precaution has been taken for the safety of the operators and the public at large as in the nuclear Power Plant. Nuclear Power has been developed to a stage at which it is today superior to other types of energy when one weighs together the factors of economy, reliability of supply and environmental effects. The problem of safety is another story. Though nuclear power looks very promising there are unresolved problems which may be worse than the power problem it is inteded to solve. The nuclear waste from nuclear power plant will take many hundreds of years to decay to a safe level, and during this time with the present method of storage, human surveillance will be needed. A potentially more serious risk is that of sabotage which, as experience during recent years lemonstrates, cannot be ignored even if there is a nigh degree of security. There is also the increased possibility as more and more reactors are built, that there will be a major failure despite the use of fail-safe concepts in the design.

In a design it is only possible to protect oneself from failures which are recognised as possible but not from those which have not been recognized.

With the formation of the "Atomic Energy Commission" by the Federal Military Government it is our hope that before Commissioning of Nuclear Power Plant in this country a meaningful and detailed consideration of the safety aspects of of the plant as raised in this paper should be looked into. The Energy Resources Unit of Nsukka and similar groups in the country should be involved in such deliberations.

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and the degree of darkening of each film is read of with the use of set standards and the dose recieved by each individual is then determined and if any individual records a dose above the set standard, the cause could be traced back to departmental fault or carelessness of the individual in question.

Care should be taken to avoid future overexposure. Medical checkups should be carried out twice or once a year. All personnel employed in radiation department should undergo periodic blood counts — particularly for the white blood cells.

CONCLUSION

The effects of ionizing radiation cannot be emphasized enough, without mentioning, that most of those, who worked with these radiations, in the early years of their discovery fell victims in one way or the other, out of ignorance of the dangers of these radiations. Madam Curie e.g. died of leukamia.

Another well known example of radiation was the Japanese 2nd — World War victims in 1945. Theirs was a case of whole body irradiation of high energy dose of up to 500R — from atomic bomb. Most of them died on the spot and those, who survived sustained very serious injuries.

Generations after them have remained victims of the genetic effects.

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